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A Numerical 4D Collision Risk Model

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Introduction

- The growing number of marine renewable energy (MRE) devices being installed worldwide has raised concerns about the possibility of harming marine fauna by collision.
- Novel sub-sea structures pose a challenge for accurately estimating collision risks. The mathematical problem of establishing an impact probability is not trivial, even if the animal motion is simplified to linear translation.
- We present a numerical algorithm to obtain such probability distributions using transient, 4-dimensional simulations of a novel MRE device concept, Deep Green, Minesto's power plant (hereafter referred to as the 'kite') that flies underwater in a figure-of-eight configuration.

Methods-Spatial Simulation

- Simulations were run by moving the kite, its tether (which connects the kite to a seabed foundation) and a seal-shaped object and checking for collisions. Four configurations were simulated, Case 1 was the baseline (Fig 1); the subsequent cases varied one parameter from the baseline.
- The geometry of the device and the object were arbitrarily defined in CAD (computer-aided design) software. Collisions are reported separately for different parts of the structure (kite and tether)
- The seal-shaped object starts from varying positions ($n = 315$) across the cross sectional area ($1 \times 1 \text{ m}$ grid)
- At each of those positions, the seal-shaped object starts with varying phase ($n = 50$) relative to the device.

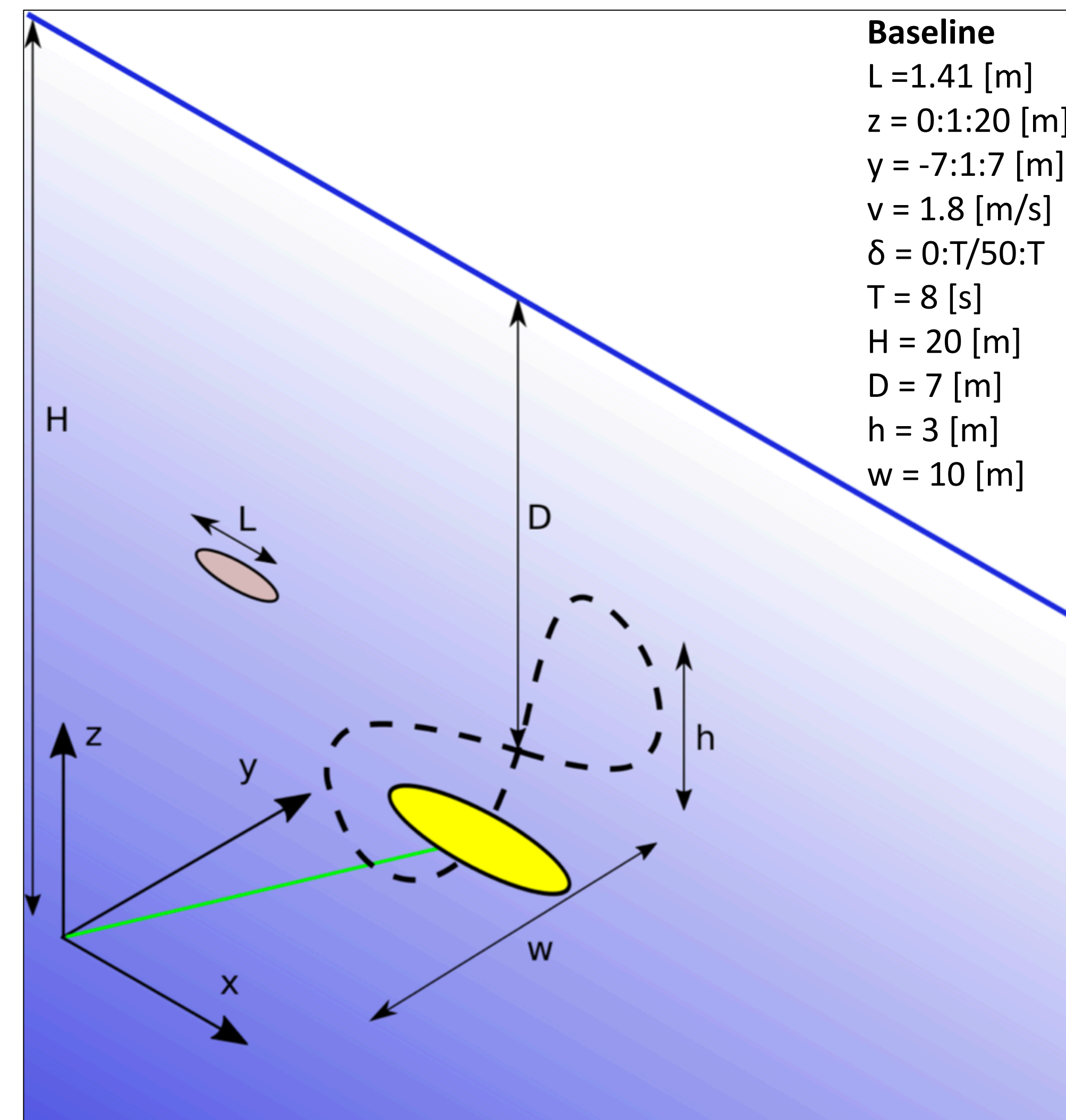


Fig. 1. Schematic of the kite (yellow), tether (green) and flightpath (dashed line) with main variables and coordinate system as used in the simulations. The pink elliptical symbol represents the animal under risk of collision. The insert provides the values used in the baseline case.

A Numerical 4D Collision Risk Model

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Methods-Analysis

- At each position the number of collisions is counted for all phase lags
- Two impact probabilities can be assessed:

$$P_A = N_{Coll}/N_{Sim}$$

$$P_{SweptA} = N_{Coll}/N_{CollPos}$$

Where: P_A refers to the entire swept area; P_{SweptA} refers only to the area swept by the structure and thus varies with mode of operation; N_{sim} is the number of all simulations; N_{Coll} is the total number of collisions; $N_{CollPos}$ is the number of positions at which at least one collision occurred for all delays tested.

Results

- Close to the bottom, where the tether amplitude is small, the path is always blocked and the impact probability is 100% (**Fig. 2**).
- Higher up in the water column, the collision probability is twice as high in the mid line, where the tether and kite passes twice per period of its trajectory.
- The collision probability distribution is much more complex in the upper water column, where the seal-shaped object can collide with the kite and tether in one phase.
- In all cases, the majority of the collisions were with the tether (**Table 1**).
- P_{SweptA} was greatest in Case 2, where the kite trajectory was increased by 1m (**Table 1**).
- P_A and the P_{SweptA} both showed little sensitivity to varying operating parameters.

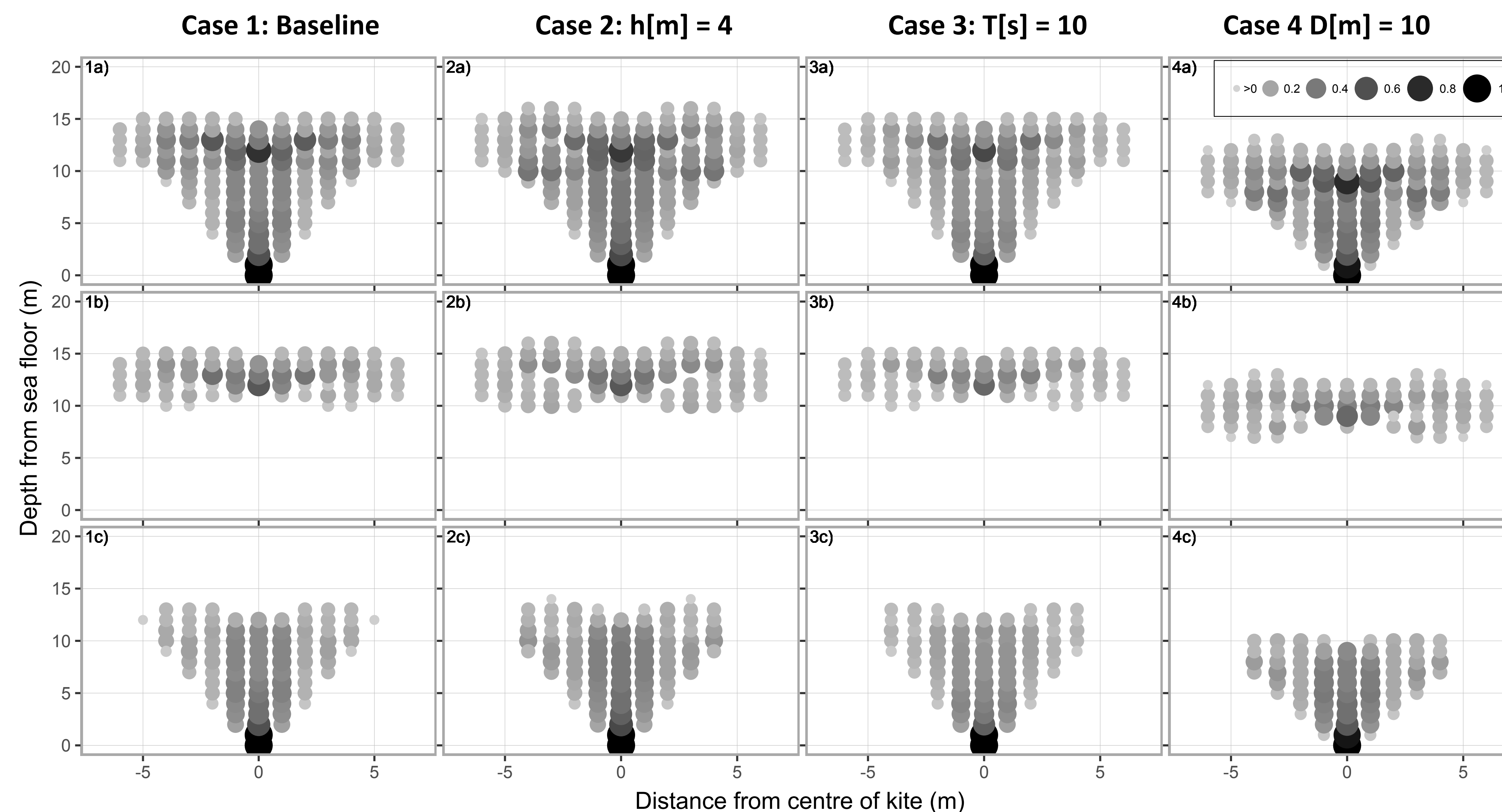


Fig. 2. Probability for a collision at each position in the cross-section between the animal and the entire structure (a), kite only (b) and tether only (c) for the four different cases (1:4), where one parameter was varied from the baseline (as noted above) for the configurations used in Cases 1, 2 and 3.

Results

Table 1. P_A of the kite, tether and device and P_{SweptA} of the device and number of collision positions ($N_{CollPos}$) are provided.

	Baseline	Case 2	Case 3	Case 4
$P_{A,Kite}$	3.77	4.41	3.11	3.77
$P_{A,Tether}$	6.16	6.74	5.42	5.37
$P_{A,Device}$	9.59	10.91	8.36	8.94
$P_{SweptA,Device}$	25.81	26.84	22.5	25.37
$N_{CollPos}$	117	128	117	111

Summary

- Our numerical tool enables computation of spatial collision probability distribution
- The method can be applied to other scenarios (e.g. wind turbines and birds), as long as geometries and motions are known.
- Results demonstrate viability of such models.
- Combination with reliable empirical field data needed for assessing the probability of collision risk of animals, such as sea birds, seals and dolphins (**Fig. 3**)
- For example, depth distributions of different animals (of similar size and speed) can now be coupled with the impact probability distribution obtained from the model to achieve more realistic environmental risk assessments.



Fig. 3. Common dolphins (*Delphinus delphis*)

